TECHNICAL BRIEF

WHO/FWC/WSH/15.02

BOIL WATER

Introduction

There are a number of circumstances in which it may be necessary to treat water at the point of use to remove or inactivate microbial pathogens. These include:

- failure of control measures, including lack of or improper disinfection and unsafe handling and storage;
- emergencies and disasters leading to inadequate sanitation, hygiene and protection of water sources; and
- uncertain quality of water sources when travelling.

A number of proven water treatment methods exist for the removal or inactivation of microbial pathogens, including chemical disinfection, filtration, flocculation/disinfection and heat. Boiling is one heat method. It is highly efficacious, killing human pathogens even in turbid water and at high altitude. However, boiling involves the high-cost use of carbon-based fuel sources and does not provide any residual protection.

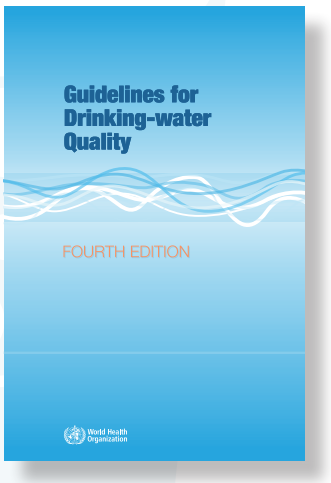
Scientific basis for the efficacy of boiling

Enteric bacteria, protozoa and viruses in liquids are sensitive to inactivation at temperatures below 100 °C. Thermal inactivation has been examined in water, sewage, milk and other liquids at temperatures close to those used for pasteurization (e.g. 63 °C for 30 minutes, 72 °C for 15 seconds) and in hot water (about 60 °C). Only a few studies have examined thermal inactivation in liquids at temperatures approaching 100 °C.

The results of these investigations, which are summarized in Table 1, show that bacteria are particularly sensitive to heat, and rapid kills – less than 1 minute per log (90%) reduction – are achieved at temperatures above 65 °C. Viruses are inactivated at temperatures between 60 °C and 65 °C, but more slowly than bacteria. However, as shown for poliovirus and hepatitis A, as temperatures increase above 70 °C, a greater than 5 log inactivation (99.999% reduction) is achieved in less than 1 minute. *Cryptosporidium parvum* oocysts are inactivated in less than 1 minute once temperatures exceed 70 °C. The data for *Giardia* cysts are more limited, but inactivation at temperatures ranging from 50 °C to 70 °C has been reported.

Conclusions

Based on these results, it is considered that the process of heating water to a rolling boil, as recommended in the WHO *Guidelines for Drinking-water Quality* (WHO, 2011), is sufficient to inactivate pathogenic bacteria, viruses and protozoa. After the water has reached a rolling boil, it should be removed from the heat, allowed to cool naturally, without the addition of ice, and protected from post-treatment recontamination during storage. If turbid water needs to be clarified for aesthetic reasons, this should be done before boiling.



World Health Organization

Table 1. Thermal inactivation of bacteria, viruses and protozoa

Organism	Temperature (°C)	Inactivation time(s)	Log_{10} reduction	Reference
BACTERIA				
Campylobacter spp.	60	300	3.9 log	D'Aoust et al. (1988)
	63	300	> 5 log	D'Aoust et al. (1988)
	60	8.2	Per log	Sörqvist (2003)
	62	15	3.5–5 log	Juffs & Deeth (2007)
Coxiella burnetii	79.4	25	No survivors	Juffs & Deeth (2007)
Escherichia coli	60	1 800	6 log	Moce-Llivina et al. (2003)
	65	< 2	Per log	Spinks et al. (2006)
	72	0.4	Per log	Sörqvist et al. (2003)
Escherichia coli O157	60	300	1.5 log	D'Aoust et al. (1988)
	64.5	300	> 5 log	D'Aoust et al. (1988)
	65	3	Per log	Spinks et al. (2006)
	62	15	< 1–5 log	Juffs & Deeth (2007)
Enterococcus faecalis	65	7–19	Per log	Spinks et al. (2006)
Klebsiella pneumoniae	72	23	Per log	Sörqvist (2003)
	65	< 2	Per log	Spinks et al. (2006)
Legionella pneumophila	58	360	Per log	Dennis, Green & Jones (1984)
Legionella spp.	80	18–42	Per log	Stout, Best & Yu (1986)
Mycobacterium paratuberculosis	72	15	> 4 log	Juffs & Deeth (2007)
Pseudomonas aeruginosa	65	5	Per log	Spinks et al. (2006)
Salmonella typhimurium	65	< 2	Per log	Spinks et al. (2006)
Salmonella choleraesuis[a]	60	300	Per log[b]	Moce-Llivina et al. (2003)
Salmonella spp. except *Salmonella seftenberg*	72	0.1	Per log	Sörqvist (2003)
Salmonella seftenberg	60	340	Per log	Sörqvist (2003)
Serratia marcescens	65	< 2	Per log	Spinks et al. (2006)
Shigella sonnei	65	3	Per log	Spinks et al. (2006)
Vibrio cholerae	55	22.5	Per log	Johnston & Brown (2002)
	70	120	> 7 log	Johnston & Brown (2002)
Yersinia enterocolitica	64.5	300	> 5 log	D'Aoust et al. (1988)
	72	0.5	Per log	Sörqvist (2003)
VIRUSES				
Adenovirus 5	70	1 260	> 8 log	Maheshwari et al. (2004)
Coxsackievirus B4	60	1 800	5.1 log	Moce-Llivina et al. (2003)
Coxsackievirus B5	60	1 800	4.8 log	Moce-Llivina et al. (2003)
Echovirus 6	60	1 800	4.3 log	Moce-Llivina et al. (2003)
Enteroviruses	60	1 800	4.3 log	Moce-Llivina et al. (2003)
Hepatitis A	65	120	2 log	Parry & Mortimer (1984)
	65	1 320	3 log	Bidawid et al. (2000)
	75	30	5 log	Parry & Mortimer (1984)
	80	5	5 log	Parry & Mortimer (1984)
	85	< 30	5 log	Bidawid et al. (2000)
	85	< 1	5 log	Parry & Mortimer (1984)
Poliovirus 1	60	1 800	5.4 log	Moce-Llivina et al. (2003)
	62	1 800	> 5 log	Strazynski, Kramer & Becker (2002)
	72	30	> 5 log	Strazynski, Kramer & Becker (2002)
	95	15	> 5 log	Strazynski, Kramer & Becker (2002)
PROTOZOA				
Cryptosporidium parvum	60	300	3.4 log	Fayer (1994)
	72	60	3.7 log	Fayer (1994)
	72	5–15	> 3 log	Harp et al. (1996)
Giardia	56	600	> 2 log[c]	Sauch et al. (1991)
	70	600	> 2 log[d]	Ongerth et al. (1989)

[a] Now known as *Salmonella enterica.*
[b] The log reductions were calculated from the results presented in Moce-Llivina et al. (2003).
[c] The log reductions were calculated from the results presented in Sauch et al. (1991).
[d] The log reductions were calculated from the results presented in Ongerth et al. (1989).

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